RARE-EARTH INFORMATION CENTER NEWS

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Spectral Behavior of Lanthanides

During the past few months several interesting papers have come to our attention dealing with the spectral properties of the lanthanide elements and some of their potential applications.

DISPEL MISCONCEPTIONS

The cathodoluminescent properties of the trivalent lanthanides in Y_2O_3 were studied by Buchanan and co-workers, *J. Appl. Phys.* 39, 4342 (1968). They noted that their results indicate, contrary to extensive prejudices, that optimum activator concentrations in Y_2O_3 are quite large (1 to 10%). The reasons for these past prejudices and the advantages of Y_2O_3 as a host over other materials are discussed.

Buchanan and co-workers also show that ions at the beginning and end of the lanthanide series contrary to accepted opinions have luminescent efficiencies equal or greater than those for the ions in the middle of the series.

INFRARED QUANTUM COUNTER

An infrared quantum counter, as noted by Esterowitz and co-workers [*Appl. Optics* 7, 2053 (1968)], is the only quantum amplifier with photon gain that can approach a noise temperature of $0\,^{o}K$. These researchers have investigated 165 different combinations of trivalent lanthanide ions in a variety of inorganic single crystal lattices.

Some of the best combinations of lanthanide ions and host crystal, and their output wavelengths were found to be: Pr^{+3} in $LaCl_3$ ($0.645\,\mu$), Er^{+3} in CdF_2 ($0.668\,\mu$), Tm^{+3} in $CaWO_4$ ($0.385\,\mu$), Ho^{+3} in LaF_3 ($0.538\,\mu$) and Er^{+3} in LaF_3 ($0.546\,\mu$).

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Diffusion

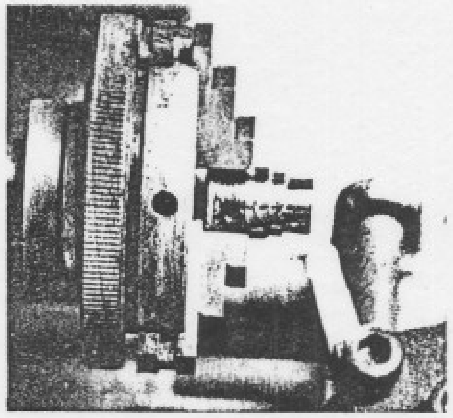
In two different papers Russian scientists have reported on the self-diffusion of yttrium and the chemical diffusion of zirconium in yttrium.

The self-diffusion results by Maskalets and co-workers [*Met. Metalloved. Chist. Metal., No. 6*, p. 189, Atomizdat, Moscow (1967); *Metal Abstracts* 1, No. 13-0770 (1968)] are the first such values reported for any rare-earth metals, as far as *RIC News* is aware. The temperature dependence of self-diffusion was given as $D = 5.5 \times 10^{-6} \exp(-30800/RT)$ for the temperature range 1000-1175^{o}C. The authors noted that in this temperature range volume diffusion is the dominant mechanism for transport of material and its activation energy is 25-30 kcal/g-at.

The chemical diffusion of zirconium in yttrium was measured from 1000 to 1300^{o}C, and the temperature dependence was determined to be $D = 4 \times 10^{-3} \exp(-38000/RT)$. These studies were reported by Rogozin, Gert and Babad-Zakhryapin in *Izv. Akad. Nauk SSSR, Metally* 1968 [3] 228. These authors also determined the chemical diffusion coefficients of molybdenum and niobium in yttrium at 1300^{o}C to be $\leq 1.8 \times 10^{-8}$ and $\leq 1.4 \times 10^{-8}$ cm^2/sec, respectively.

Rare Earths In the News

Pm METAL'S METTLE



Shown ready for machining is the ^{147}Pm ingot weighing about 100 g which was produced at Battelle-Northwest. It is the largest known amount of promethium metal ever made.

Photo courtesy of Pacific Northwest Laboratory operated by Battelle Memorial Institute for the U.S. Atomic Energy Commission.

E.J. Wheelwright at Battelle-Northwest reports that he and his associates have produced the largest amount of ^{147}Pm metal ever made – more than 100 g (see figure). Wheelwright reports a density of 7.2 g/cc of the metal, and a melting point at 1168 ± 6^{o}C, considerably higher than the 1080 ± 10^{o}C reported by F. Weigel, *Angew. Chem.* 75, 451 (1963).

HEAT RESISTANT ALLOY

A cobalt-base alloy containing yttrium may contribute to increased service temperatures of high temperature alloys. Yttrium's affinity for sulfur is said to make such

(Continued on Page 2)

Lanthanum Compound As Electrode Material

Considerable attention has been given in recent years to solid electrode voltammetry for use in electrochemical applications. Curran and Fletcher, *Anal. Chem.* 40, pp. 78, 180 and 1809 (1968), have used LaB_6 as an indicator electrode for anodic oxidation instead of mercury which is hampered by oxide formation. LaB_6 has high cathodic and anodic over-potential in aqueous solutions although the potential span is very short.

In the first study, a procedure was found for determining cathodic limit of the electrodes by reduction of water at high pH or reduction of hydrogen ion at low pH, and for the anodic limit by gross oxidation of LaB_6. The potential range was found to be 1 V. The second study involved application of LaB_6 as an indicator-electrode for acid-base titrations in aqueous solutions by using constant current potentiometry. The study demonstrated precision of a few parts per thousand of a hydrochloric acid with potassium hydroxide titration.

In the third study LaB_6 was used as an electrochemical generant of La(III) for titrations in determining Ni(II), Cu(II) and Zn(II). Constant current electro-oxidation of LaB_6 in pH-controlled solutions allows generation of known amounts of La^{+3}, where EDTA can be used for determining these three metal ions with excellent accuracy.

Friction

The influence of crystal structure and other properties on the friction and adhesion of some hexagonal metals have been studied by Buckley and Johnson, *Wear* 11, 405 (1968). A number of the hexagonal rare-earth metals were included in this study.

These authors found that the coefficient of friction was inversely proportional to the ratio of the interbasal planar spacing to the *a* lattice parameter. Thus the heavy lanthanide and yttrium metals which have the small ratios (~1.57) have coefficients of friction of about 0.7, while the light lanthanides which have large ratios (~1.61) have values of about 0.35 for this coefficient. Most of the other hexagonal metals have coefficients of friction between 0.35 and 0.7; titanium, however, is a notable exception with a coefficient of 1.2.

Buckley and Johnson also point out that in general body-centered and face-centered cubic metals have higher coefficients of friction than the hexagonal metals.

THERMIONIC CONVERTERS

Interest in high-heat-resistant materials for use in thermionic converters led to the investigation of Y_2O_3. E. S. Keddy reports that 98.7% pure Y_2O_3 withstood 1000°C in vacuo, but disintegrated at 2000°C [U.S. Atomic Energy Comm. Report LA-3822-MS (1968)], A similarly pure Y_2O_3 sample failed at 1000 °C after immersion in molten barium or lithium. Higher purity Y_2O_3 (99.5%) withstood all the above tests, although there was some surface attack by barium and lithium.

Impurities in Y_2O_3 affect heat resistance considerably and indicate that high-purity yttria must be used in high-temperature thermionic converters.

Rare Earths Common in Body

Since 1945, the determination of rare earths in the human body has been conducted by a team at the Technical University, Otaniemi, Finland. Results were negative until recent use of x-ray emission spectroscopy has proved their presence to be surprisingly common.

Yttrium was found (0.003% of the ash) in 61 out of 236 organ specimens of patients who died in Helsinki hospitals reports Erämetsä, Sihvonen and Forssén, *Ann. Med. Biol. Fenniae* 46, 179 (1968). Distribution varied and was high at 0.670% yttrium in one specimen.

Describe Rare-Earth Metal Production

The industrial methods used to produce rare-earth metals have been described in two articles during the past year. The fused salt electrolysis method was described by I. S. Hirschhorn, *J. Metals* 20, 19 (Mar. 1968), and the metallothermic method was discussed by J. L. Moriarty, Jr. *J. Metals* 20, 41 (Nov. 1968).

Moriarty is primarily concerned with the preparation of high purity rare-earth metals, whereas Hirschhorn emphasizes mischmetal and commercial grade metals.

La Improves Ti

The effect of lanthanum additions on the strength and plasticity of titanium between -196 to 800°C has been reported by Ul'yanov and Kovtun in *Izv. Akad. Nauk SSSR Metally* 1967, [4] 117 (English translations - *Russ. Metallurgy* 1967, [4] 59). Alloys containing between 0.4 and 2.2 wt % La were examined. Ul'yanov and Kovtun found that 1.8 wt % La was optimum with respect to the tensile strength; a 50% increase in strength was obtained for this addition.

Lanthanum additions also improved the ductility, especially below room temperature. A 1.0 wt % addition was found to be optimum with respect to the ductility. At -196°C the ductility of the 1.0 wt % La alloy was increased by 100% over that of pure Ti.

It would appear that lanthanum is a beneficial alloying additive for titanium especially for low temperature service applications.

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alloys nearly impervious to sulfur's corrosive effects.

COOL CONTROL RODS

A Dy_2O_3-Ni cermet developed at Douglas United Nuclear, Inc., may eliminate the need for water to cool nuclear reactor control rods. The cermet can withstand the heat of a reactor core, absorbs neutrons readily, and neither swells nor contracts under prolonged neutron bombardment.

Cobalt-RE Alloys By Electrolysis

A method for producing cobalt–rare earth alloys by electrolysis has been developed at the Reno Metallurgy Research Center of the U. S. Bureau of Mines. Morrice and co-workers reported on their process in *J. Metals* 21, 34 (Jan. 1969).

The method utilizes rare-earth oxides as feed materials to produce alloy products rich in rare-earth metals. Desired compositions can then be achieved by the addition of more cobalt.

The thermal-gradient cells used in the preparation of the alloys consisted of a graphite crucible to contain the electrolyte (usually LiF and the respective rare-earth fluoride), a graphite anode and a cobalt cathode. The authors report that, in general, all the alloy products were relatively low in impurities.

Cobalt alloys containing, individually La, Ce, Pr, Nd, Sm, Gd, Dy, Y, didymium mixture, and mixed yttrium - and cerium-group metals have been produced.

Lab Safety

Several recent studies have dealt with the biochemical hazards and exposure to radioactive ^{147}Pm and neodymium lasers.

A report by C. V. Durham, U.S. Air Force Report APGC-TR-68-53 (June 1968) contains a brief discussion of laser systems and a more detailed review of the Nd-doped laser. More specifically, this report makes recommendations for safe operation of the laser. For example, special safety goggles with an optical density of over 16 at the Nd wavelength are required for all personnel within range of the laser. Serious corneal injury to the eye can occur from infrared and ultraviolet radiation.

Exposure to ^{147}Pm has recently been of great concern. Studies have been primarily focused on the distribution in the body after exposure, ingestion, or inhalation of the isotope. Comer and Knapton, *Health Physics* 15, 166 (1968), studied the leaching effect that gastric juice has on ^{147}Pm.

Howell and King, *ibid.*, p. 174, described radiation protection problems encountered during preparation of ^{147}Pm capsules. Both Bremsstrahlung energy spectra and β-energy require strict contamination control such as inspection of rubber gloves damaged from ozone or high temperatures.

Palmer and co-workers, *ibid.* p.187, were called upon to establish realistic exposure limits and to determine the dose from accidental exposures, uptake, retention and localization of ^{147}Pm. Internally deposited ^{147}Pm was evaluated by using urinary and fecal excretion data.

The above studies with ^{147}Pm resulted from investigation of potential accidental acute intakes and recognized safety hazards of the workers at Battelle-Northwest.

LaB_6-MHD Generator

The use of lanthanum hexaboride to increase the conductivity of the working fluid in a magnetohydrodynamic (MHD) generator was discussed by Honma and Nomura, *Denki Shikensho Iho* 32, 507 (1968); *Nucl. Sci. Abstracts* 22, No. 47877 (1968). The increased conductivity of the gas is due to the favorable thermionic emission properties of LaB_6. The authors found that an electron density of 10^{14} cm^{-3} is obtained with a powder density of 10^{13} cm^{-3} for LaB_6 solid particles of 10^{-5} cm radius. (Note solid LaB_6 contains 10^{21} formula units/cm^3). The maximum conductivity was calculated to be 0.1 mho/cm for these conditions at 2300°K with nitrogen gas.

The other transport values, *e.g.* viscosity and thermal conductivity, were also calculated, and it was found that these properties were not appreciably affected by the LaB_6 powder suspension in the gas.

NEW ARC LIGHT

During the past few years Sylvania has developed a new high pressure discharge light which is claimed to be the closest anyone has ever come to duplicating natural sunlight. This light, called *Metalarc,* contains primarily mercury, and scandium and sodium oxides. The mercury lines in the discharge give rise to blue and green light and the oxides to red, orange and yellow.

The lines in the spectrum are generally less than 20A apart and when thorium is included the spacing between lines becomes less than 5A. Minor amounts of other rare earths are added to improve the spectral characteristics of the light.

Metalarc is presently being used in several sports stadiums and indoor coliseums in the United States, including Charger Stadium in San Diego. The basic ideas of Metalarc are covered by United States patents 3,334,261 and 3,407,327.

TRANSMUTATION

A novel use of lanthanum has been developed by J. W. Denison, Jr. of Trak Microwave Corp., Tampa, Fla. The lanthanum is alloyed with nickel which is used as cathodes in vacuum radio tubes.

After the tube is manufactured it is irradiated by neutrons in an atomic pile, which transmutes the lanthanum to barium. When the new tube is used the barium, which

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TUNABLE PHONON DETECTOR

A tunable, acoustical phonon detector has been demonstrated by Sabisky and Anderson, *Appl. Phys. Letters* 13, 214 (1968), by using Tm^{+2} ions in a CaF_2 host. The phonon detector is based on the optical detection of the spin population difference of an impurity ion (Tm^{+2}) through the spin-phonon interaction. The phonons were generated at $1.4^{o}K$ by a transducer using a few milliwatts of radio frequency power at 9.5×10^{9} Hertz (cycles per second).

PHOSPHORS AND SCINTILLATORS

The application of lanthanide ions for radiation detection and measurement was discussed by Buchanan and Wickersheim, *IEEE Trans. Nucl. Sci.* NS-15, [3] 95 (1968). The luminescent properties of lanthanide phosphors fall into two groups: those which exhibit sharp line spectra due to $4f \rightarrow 4f$ transitions and those which exhibit broad-band spectra due to $5d \rightarrow 4f$ transitions of the activator ion or from emission of the host itself.

In the first category the efficiencies of the phosphors are high, but decay times range from micro- to milli-seconds. Materials which have these characteristics are being studied for imaging and energy conversion applications.

In the second category phosphors have decay times in the nano- to micro-seconds range, and thus these materials look quite attractive for scintillation counting applications. The stopping power of the host material is quite important in this application. Y_2O_3, a common host material, is too light but Gd_2O_3 and/or Lu_2O_3 should be effective hosts since their stopping powers are significantly higher than that of Y_2O_3.

PHOTOSENSITIVITY

Eu^{+3} and Tb^{+3} in fluid solutions emit fluorescence which in turn is absorbed by organic sensitizers present as non-associated solutes and can be measured quantitatively. These rare-earth ion probes were one of the topics presented by N. Filipescu at the 156th American Chemical Society Meeting in Atlantic City, N. J.

Rate constants for the transfer process in several organic carbonyl compounds were taken at varying lanthanide concentrations, viscosities and temperatures. Then treatment was extended to photo-chemical reactions. The photokinetic data were consistent with an inter-molecular (collisional) transfer.

RE-OPEN AUSTRALIAN TREATMENT PLANT

The South Australian Government's uranium treatment plant at Port Pirie, closed since 1962, will be re-opened as a result of the merger of two Australian firms which have purchased the plant from the Government.

Australian Ceramic Industries Pty. Ltd. and Field Group Research Pty. Ltd. will process both uranium and rare-earth oxides at the Port Pirie plant. Re-opening of the plant is expected to boost Australia's annual export earnings by millions of dollars.

The site taken over by the new company covers 80 acres including 70 acres of residue dams left over from previous operations. South Australian Minister of Mines R. C. DeGaris said the dams contain the world's largest known supply of scandium which has potential for a new type of light. (see story on page 3).

RE'S IN TOP 100

When Industrial Research Inc. named the 100 innovations it considered the most significant technical products for 1968, the rare-earth industry took a giant step forward.

Four of the 100 products named by Industrial Research Inc. were developed around the rare earths. The four products named which employed rare earths in their manufacture included three lasers, all of which employed Nd - one of which also utilized YAG as the host material - and a solid state lamp which converts infrared radiation to visible green light by means of a LaF_3 phosphor.

Rare Earthers, hold your heads high!

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is much less soluble in nickel than lanthanum, diffuses to the surface, thereby increasing the thermionic properties of the cathode.

The advantage of these tubes is that they operate at low temperatures increasing the lifetime and reducing internal contamination.

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CLEARY AWARD WINNERS

K. J. Strnat

J. C. Olson

Capt. G. I. Hoffer

The Cleary Award of the Air Force Materials Laboratory (AFML) has been presented to Dr. Karl J. Strnat, John C. Olson and Capt. Gary I. Hoffer. They were honored for their work on magnetic materials which entailed a study of the anisotropic magnetization behavior of ferromagnetic intermetallic compounds.

The Cleary Award was established in memory of Charles J. Cleary, a member of AFML for 25 years who was assistant chief of the Laboratory at his death in 1945.

The research specifically cited for the award was reported by the three in a paper, "Permanent Magnet Properties of YCo_5 Powders," presented at the Sixth Rare Earth Research Conference in May of 1967. They have been granted a patent for a method of producing RCo_5 magnets (U.S. Patent No. 3, 424, 578) and a second patent covering the products (magnets containing RCo_5 alloys) is pending.

Dr. Strnat, principal investigator of the research, is an internationally recognized authority on magnetic materials and is credited with organizing the magnetic materials exploratory development program at AFML. Now a professor of electrical engineering at the University of Dayton, Strnat is organizing a magnetic materials laboratory at that institution.

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Polarized Electron Beams

The use of Eu(Gd)S to produce polarized electron beams has been discussed by G. Obermair (Z. *Physik* 217, 91 [1968]). In this paper Obermair describes the theory of field emission from ferromagnetic solids in which the two spin sub-bands of the conduction band are split. He concludes that highly polarized beams (as high as 100%) are possible by using ferromagnetic $Eu_{1-x}Gd_xS$ with $x = 0.055$ as the optimum concentration of gadolinium.

Polarized electron beams (8% polarization) have been produced using ferromagnetic gadolinium metal (M. Hofmann, *et al., Phys. Letters* 25A, 270 [1967]). But the use of Eu(Gd)S should lead to much more highly polarized beams.

Obermair also notes that field emission studies from ferromagnetic solids should also yield valuable information about the magnetic and band structures of these materials.

Rare Earths In the News

EXPANDS RE LINE

Molycorp has added seven additional rare earths to its product line bringing to 15 the number of rare earths it offers for sale. The seven rare earths are Tb, Dy, Ho, Er, Tm, Yb and Lu. The addition of these elements to Molycorp's line was made possible through a cooperative marketing arrangement with Shin-Etsu Chemical Industry Co., Ltd. Shin-Etsu, Japan's largest rare-earth producer, will separate Molycorp's raw material.

HOT LASER

A pulsed laser capable of heating materials to 20 million°F has been developed at Sandia Laboratories, Albuquerque, N.M. The laser incorporates four neodymium-doped glass rods. Discharging 50 joules of energy in 10 picosecond bursts, the laser's output peaks to 5×10^{12} watts, the highest power yet generated by a pulsed laser, says Sandia's Dr. Garth Gobeli.

UP RARE-EARTH STOCKPILE

In a revision of strategic stockpile objectives, the Government revised upward its stockpile objectives for rare earths. The new objective is for 6500 short dry tons, more than double the previous 3000-ton stockpile.

RE CHROMITE ELECTRODES

A new ceramic part for electrodes made of rare-earth chromite has been developed. Electrodes

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Neutron Scattering and Rare Earth Research at ORNL

The Solid State Division of the Oak Ridge National Laboratory has two neutron scattering groups which are actively studying rare-earth metals, compounds, and alloys.

The neutron diffraction group consists of W.C. Koehler, J.W. Cable, H.R. Child, and R.M. Moon as permanent staff and one graduate student, A.H. Millhouse. This group had, with M.K. Wilkinson and E.O. Wollan, first determined the complex magnetic structures of the heavy rare-earth metals by elastic scattering from single crystals.

As part of a long range program of study of the magnetic properties of the rare earths a number of alloy systems have subsequently been investigated. Most recently, the magnetic structures of single crystal specimens in the Er-Dy, Er-Tb, Er-Gd, Er-Ho, and Dy-Ho systems have been determined. Conclusions relating to the nature of the exchange interactions and of the origin of the anisotropy of the rare earths have been derived from these studies.

Recently, a large single crystal specimen of low capture cross section ^{160}Gd has been grown and the group is currently investigating the form factor of metallic Gd by means of its new polarized neutron facility at the High Flux Isotope Reactor (HFIR). The group is also studying, in collaboration with members of the neutron spectrometry group, the spin wave scattering from Gd.

The neutron spectrometry group, consisting of H.G. Smith, H.A. Mook, R.M. Nicklow, M.K. Wilkinson, with guest scientist J.C.G. Houmann and graduate student J.G. Traylor, is concerned with measurements of the inelastic scattering of neutrons from solids. Its rare earth-related projects include the determination of the phonon dispersion relations of Ho, Tb, and ^{160}Gd, and the magnon dispersion relations in the spiral regions of Ho, and Tb. This work is being done at

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Crystal Growing Methods Reviewed

New crystal growing devices and growth techniques developed over the past two years are summarized in *J. Cryst. Growth* 3, 4, 60-807 (1968). This issue comprises the Proceedings of the Second International Conference on Crystal Growth, Birmingham, U.K., July 15-19, 1968. Those papers devoted to rare-earth materials are briefly described.

Neodymium-doped calcium and yttrium aluminum garnet single crystals for solid state lasers which exhibit linear optical effects were grown by the Czochralski method. Their performance in the laser cavity varied and depended on structural defects.

A hollow cathode floating-zone melting process was also used to grow yttrium aluminum garnet and yttrium aluminate crystals. The latter compound is metastable and crystalizes incongruently from the 1 Y_2O_3/1 Al_2O_3 melt. Addition of 10% $NdAlO_3$ eliminates this. Yttrium aluminum garnet has nearly optimum properties for a laser host material. The limiting factor is the difficulty of preparing crystals with activator ions such as neodymium. Experiments to increase concentrations of these activators were conducted.

Yttrium iron garnet films were grown from molten salt solutions. Crack-free films 0.5 to 100μm thick were grown on gadolinium garnet substrates. An imperfect substrate surface tended to cause film cracking and line broadening.

Some additional compounds investigated were EuTe, EuSe and EuS grown by chemical transport and sublimation, and PrP by reaction with iodine in a closed system.

Lanthanum hexaboride is of interest for its thermoemissive properties. It was prepared in a very small crystal form by two methods: vapor-phase and liquid-phase crystallization. Its electro-optical properties were also measured.

Single crystals of Gd, Tb, Dy, Ho and Er metals were prepared by three methods: (1) RF induction floating zone technique under high purity argon, (2) recrystallization in the solid state, and (3) by DC solid state electrolysis.

Other topics included the growth of mixed cation iron garnets from flux in yttrium gallium and yttrium calcium silicate systems, and growth of Ce_2O_3 and La_2O_3 by an arc transfer process.

Binary rare-earth oxide solid solution crystals such as La_2O_3-Er_2O_3 were grown by the Verneuil method.

REFRACTORY PrP

The highest melting point ever observed for a rare-earth compound was reported by K.E. Mironov in a description of his method of preparing PrP [*J. Cryst. Growth* 3, 4, 150 (1968)]. The melting point reported by Mironov was 2850±50°C.

The next highest reported melting point is that of YB_6, 2800°C. Next in line are ScN and YN which melt at 2550°C; Lu_2O_3 at 2490°C, the highest melting oxide; CeS at 2450 °C; and GdC_2 and YC_2 at 2415°C.

Although PrP's high melting point makes it a potentially attractive refractory material, other data reported earlier indicate that its high temperature applications may be limited. For example, K.A. Gingerich found that PrP has a phosphorus partial vapor pressure of 10^{-5} to 10^{-9} atm. between 820 and 1275°C (*J. Am. Chem. Soc.* 87, 1660, [1965]). Furthermore Mironov and co-workers found that PrP will oxidize in air above 700°C (*Dokl. Akad. Nauk SSSR* 176, 841 [1967]; English translation, *Doklady Chem.* 176, 873 [1967]).

Faculty Award To LeRoy Eyring


LeRoy Eyring

Dr. LeRoy Eyring, chairman of the chemistry department, Arizona State University (ASU), Tempe, Ariz., has received the ASU Alumni Association's Faculty Achievement Award for 1969.

In naming Eyring as the 1969 recipient, the Alumni Association cited his achievements in solid state chemistry research, his worldwide reputation as an authority on rare-earth oxides, and his ability, as department chairman, to stimulate and encourage the research and teaching excellence of the faculty.

A member of the ASU faculty since 1961, Dr. Eyring in his eight years as chemistry department chairman has built the chemistry department into one of the strongest in the ASU College of Liberal Arts. His was one of the first two departments at ASU to qualify to offer doctor of philosophy degree programs.

Dr. Eyring has been active in the field of rare-earth research for about 20 years and has lectured extensively in Europe and the United States. He was chairman of the Third Rare Earth Research Conference in 1964.

Dr. Eyring has published more than 40 papers in scientific journals and is the editor of three review volumes dealing with the rare earths and with high temperature chemistry.

He is only the sixth ASU faculty member ever named for a Faculty Achievement Citation.

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prepared with the new ceramic are electrically conductive from ambient temperature up to their melting temperature. The inventor is M. Foëx of the French Atomic Energy Commission.

Transparent RE Oxides

Transparent Y_2O_3 has been obtained by pressure forging techniques, Spriggs and Atteraas, p. 701 in *Ceramic Structure,* Fulbrath and Pask, eds., Wiley, New York (1968). Several other desired properties resulting from this technique include enhanced densification rates, controlled porosity or full density, composite fabrication, pressure bonding single and polycrystalline ceramic materials together, and oriented microstructure.

Single-phase Y_2O_3 has shown crack-free, dense, and highly transparent properties after press-forging as compared to the opaque sample which is obtained from conventional pressure-sintering. Microstructures showed elongated grains perpendicular to direction of pressure and x-ray texture studies revealed preferred orientation in pressure-forged samples. Other materials of interest to which the technique was successfully applied were lanthana, samaria and ceria.

Stone is Grace V.P.

R.L. Stone, head of W.R. Grace & Co.'s rare-earth department, has been named a vice president of the firm's Davison Chemical Division, the parent division of Grace's rare-earth department.

RE Industry Reappraisal

The rare-earth industry, which experts (including *RIC News*) predicted would have its greatest year in 1968, is currently the subject of intensive review as prognosticators try to figure out what happened. More accurately, they are trying to figure out *why* it happened.

One of the big markets for rare earths, the color television industry, did not come through even as it had expected. Color television sales of 5 million sets in 1967 were supposed to climb to 7 million sets in '68, but leveled off at 5.6 million sets.

Some say that the industry is in the same position it was prior to the color television boom—waiting for a research "find" to create new markets. Despite the current lag in rare-earth demand, the industry is still considered a growth industry.

This optimism stems from the flexibility of the industry itself. Many producers are looking toward specialized markets and are tailoring production accordingly.

Another reason for optimism stems from the problem of rare earth separation—you cannot separate one without separating them all. In producing one or several rare earths for a specific market, you cannot help but increase the availability of the rest of the series. This ready availability of many rare earths not presently used extensively is expected to attract other manufacturers to them.

For a worldwide review of the rare-earth industry see *Industrial Metals* No. 14, Nov. 1968, pp. 9-27, and No. 16, pp. 35 and 36, where supplemental discussions of Japan's and India's rare-earth industry appear. India's rare-earth industry is also reviewed in *Nuclear News* 12, April 1969, pp. 22 and 24. The United States industry was featured in *Chemical and Engineering News* 47, No. 13, Mar. 24, 1969.

NEUTRON FILTER

Scandium is aiding researchers at Idaho Nuclear in their investigation of the nuclear properties of structural and fuel materials that will be used in the fast breeder reactors.

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NEW BOOKS

SPECTRA AND ENERGY LEVELS

An excellent book by the late G.H. Dieke, edited by H.M. and Hannah Crosswhite, *Spectra and Energy Levels of Rare Earth Ions in Crystals* has been published by Interscience, New York (1968). The cost of this book is $13.95.

There are two valuable chapters in this book which one might not expect to find in a volume such as this. They are "Crystals Available for Study" and "Experimental Procedure." In addition to these two, there are twelve more chapters: "Introduction"; "Historical"; "The Rare Earths"; "Spectra and Levels of the Free Ions"; "The Crystal Field"; "Crystal Symmetry and Structure of the Spectrum"; "Intensities, Selection and Polarization Rules"; "Comparison with Empirical Data"; "Zeeman Effect and Magnetic Properties"; "Divalent Rare Earth Ions in Crystals"; "Review of the Empirical Data"; and "Line Structure."

The book is well illustrated and contains many tables, some of which may be as long as 6, 11 or 30 pages. The original literature is well documented with more than 650 references. Author and subject indexes are also included.

This 400+ page volume should be of value to those of us who are working on the spectra, optical behaviors, magnetic properties, NMR, EPR and other solid state properties, especially those involving the crystalline environment of these elements and their ions.

SCAN DE UM

There is much interest these days in the physical behavior of scandium and scandium-rich alloys as evidenced by the number of papers presented on this topic (six) at the American Physical Society Meeting in Philadelphia, March 24-27, 1969. Most of the work, both theoretical and experimental, is being carried out at the Argonne National Laboratory, and in part in collaboration with Northwestern University.

Earlier work which showed some unexplainable anomalies in the low temperature elastic constants and heat capacity is the apparent stimulus for this current flurry of activity.

These papers dealt with electron transport properties from both a theoretical and an experimental approach, nuclear magnetic relaxation measurements, magnetic anisotropy, and the calculated band structure and Fermi surface of scandium. As a result of the theoretical studies, a new type of dynamic interaction, an electron-antiparamagnon interaction, was proposed to explain the observed behaviors.

The sixth paper, from Iowa State University, described the phonon dispersion curves of scandium as measured by inelastic neutron scattering.

(Continued from Page 3)

Scandium permits 2 keV neutrons to pass through it but stops neutrons of all other energies; in effect, it acts as a neutron filter. An 84 cm (33 in.) long piece of scandium metal placed in one of the beam holes in Idaho Nuclear's Materials Testing Reactor yields a high intensity monoenergetic beam of 2 keV neutrons.

The scandium beam experiements are used by designers to determine how the safety of a fast reactor is affected as the temperature increases.

MEETING

8TH RARE EARTH CONFERENCE

Arrangements are going ahead for the 8th Rare Earth Research Conference which will be held in Reno, Nevada, April 19-22, 1970. T.A. Henri, chairman, has sent word that sessions will be held in the meeting rooms of the Reno Chamber of Commerce with supplemental facilities being made available in the municipal theater-auditorium. Advance notices concerning the conference are now in preparation.

(Continued from Page 1)

Olson and Hoffer are still members of the Air Force Materials Laboratory staff.

The development of the rare earth-cobalt magnetic materials has sparked worldwide interest in the new magnetic material. Bell Telephone Laboratories, General Electric and Raytheon in the United States, Philips in Holland, and Matsushita Company in Japan all have been working with the Strnat, Olson and Hoffer-developed materials. They have prepared magnets with outstanding properties mostly based on a $SmCo_5$ alloy.

(Continued from Page 2)

the computer controlled triple axis spectrometer at the HFIR. Work is planned for isotopically enriched specimens of Dy and Er.

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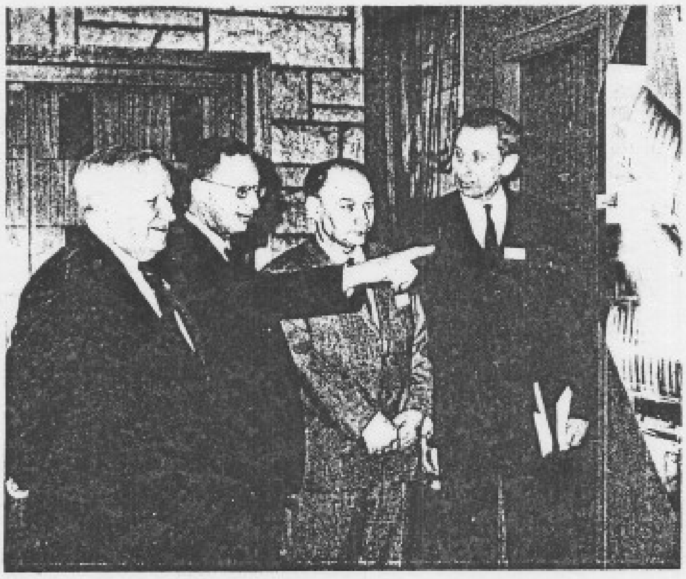


This internationally known group of rare-earth researchers got together to view a display of French-produced rare earths during the Paris-Grenoble meeting. From left are F.H. Spedding, Iowa State University, Ames, Iowa, USA; E.F. Bertaut, National Center for Scientific Research, Grenoble, France; E.M. Savitskii, Institute of Metallurgy of A.A. Baikov, Academy of Sciences, U.S.S.R., Moscow; and Felix Trombe, National Center for Scientific Research, Bellevue and Montlouis, France.

International Conference

In early May the French National Center for Scientific Research sponsored and served as hosts for a six-day meeting on the rare earths. Furthermore, their gracious financial assistance enabled a number of non-French scientists to attend the Conference who otherwise might not have participated. Of the 200 persons attending the Conference, most came from Western Europe, but there were also scientists from Canada, Hungary, Romania, the U.S.A. and the U.S.S.R.

The first three days (May 5-7) of the meeting were spent in Paris, where the Conference dealt with the metallurgy, chemistry and optical behavior of the rare earths (a complete list of the papers presented at the Conference follows this story). The last half of the Conference (May 8-10) was held in Grenoble, where the emphasis was on solid state physics.

The Paris portion of the Conference was organized by Dr. F. Trombe and his co-workers and the Grenoble portion by Dr. E.F. Bertaut and his co-workers. Both groups are to be commended for the excellent Conference and their kind hospitality.

The keynote speaker at the Conference was Dr. F.H. Spedding, Iowa State University, Ames, Iowa, who spoke on 'The Preparation, Handling and Properties of "Pure" Rare Earth Metals.'

All attendees were given a copy of the abstracts of the papers presented at the Conference. Furthermore, the Conference Proceedings will be published in two volumes, one for the Paris half and the other for the Grenoble half. As soon as these volumes are published *RIC News* will announce their availability.

Fifteen Firms Support RIC

The publication of *RIC News* for at least another year, and the resumption of RIC's inquiry answering function have been assured through a broadened base of financial support from 15 of the world's leading rare-earth producers.

Begun as a U.S. Atomic Energy Commission information center in 1966, RIC faced extinction when the AEC was forced to withdraw its support of the Center in 1968. However, grants to Iowa State University's Institute for Atomic Research from five American rare-earth companies made it possible to continue publication of *RIC News.*

The original five industrial supporters of RIC have been joined by 10 more companies representing seven countries, including the U.S., for support of the Center through July 1970.

Financial support for RIC now comes from American Metallurgical Products Co., USA; American Potash & Chemical Corp., a subsidiary of Kerr-McGee, USA; Elettrochimical Italiana delle Terre Rare, Italy; Th. Goldschmidt A.-G., Germany; W.R. Grace & Co., USA; Indian Rare Earths, Ltd., India; Leico Industries, Inc., USA.

Michigan Chemical Corp., USA; Molybdenum Corporation of America, USA; Pechiney-Saint Gobain, France; Research Chemicals Division, Nuclear Corporation of America, USA; Ronson Metals Corp., USA; Shin-Etsu Chemical Industry

(Continued on Page 7)

International Conference Program

PARIS SESSIONS

1. General Metallurgy

F.H. Spedding, B.J. Beaudry, J. Croat et P. Palmer: *The preparation, handling and properties of «pure» rare earth metals.* *

E.M. Savitskii, V.F. Terekhova, R.S. Torchinova, I.A. Markova, O.P. Naumkin et V.E. Kolesnichenko: *L'étude des propriétés physiques et chimiques d'alliages des terres rares.* *

E. Parthé: *Quelques principes structuraux des composés ternaires métalliques des terres rares.* *

K.A. Gschneidner Jr: *Alloy theory of the rare earth metals.* *

G. Schiffmacher, G. Malé et F. Trombe: *Préparation des métaux des terres rares par réduction métallothermique de leurs oxydes.*

2. Oxides and Ternary Oxides

G. Weber et L.R. Eyring: *The transport properties of rare earth oxides.* *

S. Anderson: *The change of oxide structures by anion sustitution.* *

R. Hoppe: *Die ternären Oxide der seltenen Erden mit Alkalimétallen.* *

H. Bärnighausen: *The crystal structure of* $LiEu_3O_4$*.

M. Gondrand et A. Waintal: *Étude des composés* $TLiO_2$. *Mise en évidence d'une nouvelle forme* $TLiO_2$ *(T étant une terre rare) obtenue par haute pression et à haute température.*

R.A. Paris, J.M. Paris, G. Szado, G. Paris et B. Vulliermet: *Obtention d'oxydes mixtes et de solutions solides contenant des lanthanides.*

J. Loriers, G. Villers, F. Clerc et S. Lacour: *Les grenats de néodyme-fer-scandium. Conditions d'existence. Étude cristallographique et propriétés magnétiques.*

A. Rouanet: *Diagrammes de solidification et diagrammes des phases de haute température des systèmes formés par la zircone avec les sesquioxydes des lanthanides.*

3. Metals and Alloys

K.H.J. Buschow: *Rare Earth Cobalt intermetallic compounds.*

R. Lemaire et D. Paccard: *Structures cristallines du composé* TbNi.

G. Bruzzone, M.L. Fornasini et F. Merlo: *Rare earth-zinc compounds close to the* 1:4 *composition.*

A. Palenzona et E. Franceschi: *The crystal structure of* RE_2T1 *compounds.*

G.L. Olcese: *Sur la structure électronique du cérium dans ses composés intermétalliques binaires.*

C.E. Lundin: *The structural characteristics of the samarium-type phase in intra-rare earth binary alloy systems.*

A. Iandelli et A. Palenzona: *Binary phase diagrams of ytterbium with Cu, Ag, Au.*

A. Percheron: *Étude du système étain-samarium.*

C. Boulesteix, M. Gasgnier et C. Henry La Blanchetais: *Étude des couches minces de samarium en microscopie électronique.*

4. Chemistry and Crystallography of Salts: Carbides, Nitrides and Phosphides, Etc.

C.K. Jørgensen: *Les déviations de trivalence dans les groupes f et le paramètre (E - A).* *

G. Busch, E. Kaldis et P. Wachter: *Synthesis, crystal growth and physical properties of some rare earth nitride phases.*

N. Lorenzelli, J. Melamed et J.-P. Marcon: *Recherche de nitrures de terres rares sous-stoechiométriques. Étude des oxynitrures de gadolinium.*

A. Laplace et R. Lorenzelli: *Étude de monocarbures d'europium et d'ytterbium. Structure cristalline et valence des ions métalliques.*

J.S. Anderson et A.N. Bagshaw: *Thermodynamic studies of lanthanum, cerium and neodynium carbides.*

G. Lobier: *Étude par rayons X et par diffraction neutronique des carbohydrures et sulfohydrures d'yttrium.*

H. Barrere, J. Daou et R. Viallard avec la collaboration de J. Bonnet, J.-L. Leroy, Nguyen-Thi Kim Min: *Progrès récents dans la connaissance des hydrures de lanthanides.*

K.E. Mironov, I.G. Vasil'eva, Yu. I. Mironov et Ya. V. Vasil'ev: *Thermal stability of cerium and gadolinium monophosphides.*

D.A. Johnson et J.D. Corbett: *The relative stabilities of the rare earth metal diiodides.* *

5. Optical Properties of Oxides and Salts

D.J. Newman, G.E. Stedman et M.M. Curtis: *The use of simplified models in crystal field theory.*

J.-P. Briffaut: *Champ cristallin au site de* Eu^{3+} *dans une série d'orthovanadates.*

C. Bonnelle et R.C. Karnatak: *Étude par spectroscopie X des distribution 4f du gadolinium et de l'europium dans le métal et l'oxyde.*

F. Gaume-Mahn, C. Linares et G. Boulon: *Intérêt de matrices oxygénées à base de terres rares pour l'étude de la fluorescence des ions* Eu^{3+} *et* Bi^{3+}.

S. Natansohn: *Luminescence phenomena in rare earth activated lanthanum oxychlorides.*

*Invited speaker

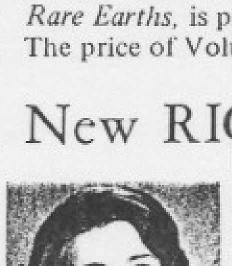
Rare-Earth Progress

The third volume of *Progress in the Science and Technology of the Rare Earths,* L. Eyring, Ed. (Pergamon Press, New York, 1968) has been released. This authoritative book surveys rare-earth metals and compounds and describes their applications in science and technology.

Included in this volume are chapters on electronic structure of alloys and inter-metallic compounds; optical transitions in crystals; coordination chemistry; liquid-liquid extraction; crystal chemistry of binary and ternary chalcogenides; monocarbides and mononitrides; thermodynamic properties of oxides; structures of oxides and hydroxides; thermodynamic and magnetic properties of chalcogenides, pnictides, halides and semi-metallic compounds; and rare-earth metal-refractory metal systems.

This series, *Progress in the Science and Technology of the Rare Earths,* is prepared biannually. The price of Volume 3 is $25.00.

New RIC Staffer



Nancy Ann Kippenhan has joined the staff of RIC as a half-time junior scientist. She replaces Mrs. Charla Bertrand.

Mrs. Kippenhan will be responsible for collecting and compiling new rare-earth data that become available, for researching and drafting replies to inquiries (a service RIC is resuming, see Page 1), and newswriting.

The new RIC staffer is a 1965 graduate of Lake Forest College, Lake Forest, Ill., with a B.A. in chemistry. She has been a research chemist with Abbott Laboratories, North Chicago, Ill., for the past four years. She is a member of the American Chemical Society and Phi Beta K pa.

M. Laveant: *Etude de quelques facteurs modifiant l'émission de l'ion* Eu^{3+} *dans les matrices* Y_2O_3 *et* Gd_2O_3.
J.-P. Denis et J. Loriers: *Préparation et propriétés de luminescence du phosphate de cérium et des phosphates mixtes de cérium-lanthane activés au terbium.*
R.K. Datta et A. Pekar: *Reinvestigation of the system* $Y_2O_3 - B_2O_3$.
A. Babusiaux, M. Baron et J. Loriers: *Luminescence de l'europium dans des composés de terres rares par excitation interionique à l'aide du promethium 147.*

6. Chemistry and Crystallography of Salts with Oxygen Anions

A.N. Christensen: *Coordination of rare earth ions in hydrothermally prepared compounds.* *
P. Caro, J.-C. Achard et O. de Pous: *Propriétés physiques et stabilité thermique des carbonates, hydroxycarbonates et oxycarbonates de la série des terres rares.*
N.S. Stroganoba et L.V. Rousaikina: *Combinaisons de l'europium (II) et (III) et leur utilisation dans la pratique de l'analyse.*
I. Grenthe: *Steric effects in the formation of rare earth glycolate complexes.*
J. Albertsson: *Steric effects in some nine-coordinated lanthanide complexes.*
M. Beucher: *Données cristallographiques sur les polyphosphates de terres rares du type* $t(PO_3)_3$.
I.A. Bondar: *La synthèse des monocristaux des silicates et des germanates de terres rares.*
G. Garton et B.M. Wanklyn: *Crystal growth of gadolinium and dysprosium orthovanadates.*

7. Chemistry and Crystallography of Salts: Sulfides, Selenides, Etc.

M. Julien-Pouzol, M. Guittard et O. Gorochov: *Étude des systèmes* $L_2Se_3 - Cu_2Se$ *et* $L_2Se_3 - Ag_2Se$.
M. Matrie, Nguyen Huy-Dung, N. Nikolova, M. Lepeltier et J. Flahaut: *Systèmes formés entre les sulfures* L_2S_3 *des terres rares et les autres sulfures* MS *des éléments de transition.*
P. Laruelle, J. Etienne et G. Collin: *Étude cristallographique du remplacement isomorphe de l'aluminium par des éléments divalents ou tétravalents dans des composés isotypes de* $L_6Al_{3.33}S_{14}$ *où L est une terre rare.*
S.A. Kutolin, R.N. Samoilova, G.I. Chramtsov et G.K. Chramtsova: *Investigation of dispersion correlations in polycrystal* R_2S_3 *type sulphides of rare earth metals.*
V.K. Val'tsev, A.A. Kamarzin et N.A. Doroshenko: *The synthesis of rare earth sexosulphides in natrium rhodanate melt.*
S. Aleonard et C. Pouzet: *Étude cristallographique de quelques fluorures complexes de terres rares de formule* A_2NaTF_6.
J. Portier, B. Tanguy, A. Morell et M. Pouchard: *Nouvelles structures d'hotes oxyfluores des ions lanthanidiques.*

GRENOBLE SESSIONS

1. Magnetism

J.-L. Feron et R. Pauthenet: *Propriétés magnétocristallines des terres rares monocristallines de la deuxième série.*
H. Bartholin et D. Bloch: *Effet des pressions hydrostatiques et uniaxiales sur les températures de transition magnétiques de monocristaux de terres rares (Gd, Tb, Dy, Er).*
T.S. Al-Bassam et W.D. Corner: *Magnetic domain structures in gadolinium.*
J. Pierre: *Propriétés magnétiques des composés équiatomiques terres rares-métaux nobles. Relation avec la structure de la bande de conduction.*
J.T. Christopher et K.N.R. Taylor: *The magnetic properties of* $Gd(CoNi)_2$.
J.-L Feron, D. Gignoux, R. Lemaire et D. Paccard: *Propriétés magnétiques des composés* T_3M *entre les métaux de terres rares et les métaux de transition de la première série.*
A. Marchand et R. Lancia: *Résonance magnétique à 9,3 GHz de composés intermetallique cobalt-terre rare.*
E. Burzo, I. Pop et V.L. Tchetchemikov: *Le ferromagnétisme du composé intermétallique* Co_2Gd.
W.P. Wolf, H.E. Meissner, C.A. Catanese et P.D. Scott: *Magnetic properties of the Rare Earth hydroxides.* *
R.L. Cohen, S. Hufner et K.W. West: *A first order phase transition in europium metal.* *
G.T. Meaden et N.H. Sze: *Des fluctuations et des indices critiques près de la température de Néel de l'europium.*
J. Schweitzer et J. Yakintos: *Structures magnétiques des composés intermetallic terre rare - cobalt de formule* TCo_3.
B.J.C. van der Hoeven Jr.: *The effect of shape and surface on thermal properties of ferromagnets at the Curie point.*
P. Fischer, W. von Wartburg, P. Schwob et O. Vogt: *Neutron diffraction evidence for magnetic phase transition in europium selenide.*
D.T. Teaney et V.L. Moruzzi: *The magnetic specific heat of EuO, EuS, impure Eu, and Ba. 12° to 300° K.*
R. Suryanarayanan et C. Paparoditis: *Préparation et propriétés des tellurures d'europium et d'ytterbium et de leurs solutions solides avec PbTe.*
O. Gorochov, Vo Van Tien, Nguyen Huy-Dung, Mlle E. Barthelemy et J. Flahaut: *Proprietes électriques et magnétiques de quelques composés ternaires contenant de l'europium II.*
S.J. Cho: *Spin-polarized energy bands in europium chalcogenides by the augmented-plane-wave method.*

MEETING

8TH RARE EARTH CONFERENCE

The Committee for the 8th Rare Earth Research Conference has issued a call for abstracts from participants intending to present papers at the April 19-22, 1970 meeting. The deadline for abstracts is Oct. 15, 1969, according to T.A. Henrie, chairman.

Thirteen sessions to be held in five meeting periods are planned. Topics to be covered are solid state reactions, chemistry, physics, metallurgy, geology, and industrial processes.

Abstracts and requests for information about the Conference should be addressed to:

T.A. Henrie, Chairman
8th Rare Earth Research Conference
% U.S. Bureau of Mines
Reno, Nevada 89505 U.S.A.

Letters

To the Editor:

A recent item in *RIC News* entitled "Transparent RE Oxides" (Vol. IV, No. 2, p. 3) implies that preparation of transparent Y_2O_3 by press forging is a new achievement. I would like to call your attention to the paper by R.A. Lefever and John Matsko, "Transparent Yttrium Oxide Ceramics," *Mat. Res. Bulletin* 2, 865 (1967), in which the preparation of completely transparent discs of Y_2O_3 by vacuum press forging is described. The procedure involves a single vacuum hot swaging operation requiring temperatures and pressures on the order of only 950° C and 10,000 psi, respectively. . .

R.A. Lefever
Sandia Laboratories
Albuquerque, N.M. 87115

Rare! Earthly Goofs

Vol. IV, No. 2, June 1969.

If you had trouble finding the source material for our "Reappraisal" story, it's because we couldn't find it ourselves in the references listed. The worldwide review was contained in *Industrial Minerals*, NOT in *Industrial Metals* as reported. Also, the review of India's RE industry begins on page 23 instead of on page 22 in *Nuclear News*, Vol. 12. Sorry about that.

C.K. Jørgensen: *Le couplage de spin intra-atomique et l'extrême contraire des spins distants.*
B.R. Cooper: *Magnetic ordering and thermodynamic properties of induced moment systems.*
P. Boutron: *Anisotropie de la susceptibilite paramagnetique: application aux terres rares.*

2. Neutron Diffraction

W.C. Koehler et A.H. Millhouse: *Magnetic properties of Er-based binary rare earth alloys.* *
C. Beele et R. Lemaire: *Propriétés magnetiques et structures magnétiques des composés equiatomiques de type DyAl entre l'aluminium et les métaux de terre rare.*
R. Lemaire et D. Paccard: *Propriétes magnetiques et structures magnétiques des composés equiatomiques terre rare-nickel.*
T.J. O'Keefe, G.J. Roe et W.J. James: *The Ho-Fe binary system and related magnetic properties.*
Nguyen Van Nhung, J. Sivardiere et A. Apostolov: *Structure magnétique du monosiliciure d'erbium ErSi.*
H.B. Moller, M. Nielsen et A.R. Mackintosh: *Inelastic neutron scattering in rare earth metals.* *
A.D.B. Woods, M.W. Stringfellow, T.M. Holden et B.M. Powell: *Exchange and crystal field interactions in erbium and holmium from inelastic neutron scattering measurements.*
E.F. Bertaut, K. Schweitzer et F. Tcheou: *Ordre magnétique de la terre rare dans les grenats.*
S. Quezel, E.F. Bertaut et G. Quezel: *Structures magnétiques et théorie des représentations dans les oxydes cubiques des terres rares.*
R. Ballestraci, G. Quezel, J. Rossat-Mignod et F. Tcheou: *Propriétés magnétiques des oxysulfures de terres rares.*
M.C. Montmory, E.F. Bertaut et K. Lövold: *Structure cristallographique et magnétique de* Er_6WO_{22}.
G. Busch et F. Levy: *Distorsion tétragonale et trigonale du réseau de certains composés trivalents des terres rares.*
M. Mercier et P. Bauer: *Mesures magnétoélectriques sur quelques cobaltites, aluminates et ferrites de terres rares.*
G. Lee, M. Mercier et P. Bauer: *Mesures de l'effet magnétoélectrique sur les grenats aux basses températures.* *
A. Apostolov, A. deCombarieu, J. Mareschal, J.-C. Michel, J. Peyrard et J. Sivardière: *Chaleurs spécifiques, propriétés métamagnétiques, aimantations en champ faible et structures magnétiques des orthoferrites de terres rares.*
J.D. Cashion, A.H. Cooke, L.A. Hoel, D.M. Martin et M.R. Wells: *Magnetic properties of gadolinium ortho-vanadate.*
W.E. Wallace, R.S. Craig, A. Thompson, C. Deenadas, M. Dixon, M. Aoyagi et N. Marzouk: *Heat capacity studies of intermetallic compounds containing rare earth elements.* *
E.F. Westrum Jr.: *Thermal and Electronic Behavior of the Rare Earth Hexaborides from Cryogenic Calorimetry.*
E. Belorizki, M.J.M. Leask et K.J. Maxwell: *Co-operative optical excitation in Erbium Aluminum Garnet.*
S. Hufner: *Optical investigations of magnetic rare earth oxides with the garnet and perovskite structure.*
G.M. Kalvius, G.K. Shenoy et B.D. Dunlap: *Hyperfine interactions in* Er_2O_3 *and* Yb_2O_3 *between 20°K and 1.5°K.*
J.-M. Baker et G. Currel: *Orbit-Lattice Interactions for Rare Earth Ions in Cubic Crystals: EPR under uniaxial stress.*
E.D. Jones: Pr^{141} *and* Tm^{169} *Nuclear Magnetic Resonances in Van Vleck Intermetallic Paramagnets.*

3. Resistivity, Kondo Effect

A. Blandin: *Interactions d'échange dans les métaux et alliages de terres rares.*
J.-J. Rhyne: *Anomalous hall effect in rare earth metals.*
F.M.K. Lodge et K.N.R. Taylor: *Electrical conductivity of dysprosium thin films.*
H.H. Hill et R.O. Elliott: *Virtual bound states in plutonium: the Kondo effect in LaPu and PrPu alloys.*
H.J. van Daal et K.H.J. Buschow: *Investigations on electrical and magnetic properties of rare-earth intermetallic compounds.*
S. Methfessel: *Magnetic, electric and optical properties of rare earth chalcogenides.*
B. Coqblin: *Considérations théoriques sur les changements de valence de terres rares.*
C. Chr. Schüler: *Optical properties of rare-earth metals.*

Rare-Earth Halides

A 280-page book by D. Brown, *Halides of the Lanthanides and Actinides,* has been published by Wiley - Interscience Publishers, John Wiley and Sons, New York (1968). Its cost is $11.00.

Halogen and oxyhalogen complexes of lanthanides and actinides including yttrium and scandium are extensively reviewed. The first chapter presents an overall picture of halide chemistry and its special problems. Fluorides, chlorides, bromides and iodides and their respective oxyhalides are dealt with in four succeeding chapters each of which are subdivided by valence states. Preparation, chemical and physical properties, structures, and halogenocomplexes are discussed. Differences and similarities between the lanthanide and actinide series are presented in parallel.

Thermochemical data, infrared vibrational frequencies and mixed halides of trivalent and tetravalent uranium are listed in separate appendices for convenient location. Literature coverage through the end of 1967 is provided.

Chelates Point to Novel Separation

Thermodynamic properties have recently been reported on a series of remarkably volatile and thermally stable lanthanide chelates, *J. Am. Chem. Soc.* 91, 3476 (1969).

J.E. Sicre and co-workers at the Aerospace Research Laboratories, Wright-Patterson Air Force Base, Ohio, have found large differences in the vapor pressures, heats of vaporization, and heats of sublimation of the lanthanide chelates of 2,2,6,6-tetramethyl-3,5-heptanedione, H(thd). Their findings corroborate the trend detected earlier by gas chromatography and reported by Eisentraut and Sievers in 1965. Complexes of the higher atomic number lanthanides are more volatile than those of the lighter, larger ones; this is an effect of the lanthanide contraction.

Vapor pressure as a function of temperature was measured for 13 lanthanide complexes. The differences were large enough to permit novel separation of these elements.

A recent patent of Eisentraut and Sievers (U.S. Patent 3,429,904) describes the use of the tetramethylheptanedionato complexes to separate cleanly and purify lanthanide mixtures by fractional sublimation. For example $Lu(thd)_3$, $Yb(thd)_3$, and $Tm(thd)_3$ sublime at temperatures about 100°C lower than those required for $La(thd)_3$, $Pr(thd)_3$ and $Nd(thd)_3$. A thermal gradient fractional sublimation apparatus is used to effect separation.

Rare Earths In the News

NORWEGIAN RE PRODUCER

The Metal Extractor Group of Norway, MEGON, was formed in April of this year by ten Norwegian industrial firms to produce rare earths (primarily yttrium oxide) and other metals and materials from various Norwegian ore sources.

CANADIAN YTTRIUM OXIDE

Denison Mines has announced that it is resuming production of yttrium oxide from tailings of the uranium mining operation. This material is being shipped to Molycorp for further processing.

1000 WATT Nd LASER

Sylvania has announced it will be producing a 1000 watt CW Nd-doped yttrium aluminum garnet laser. Delivery on the first models is scheduled for January 1972.

ULTRAVIOLET Nd-DOPED LASERS

The use of a frequency doubler and a special output mirror which is reflective to 1.06μ but transmits 0.53μ enables quadrupling the frequency of Nd lasers to 0.265μ. The Nd-doped glass laser which is manufactured by Korad, has an average energy of 5 mjoules, and is particularly useful for initiation of photochemical reactions and the study of living tissues.

Rare Moon Dust

"To all scientists this is a very, very exciting time," claimed a geologist at the Lunar Receiving Laboratory as he opened the first samples from the moon. Soon to share his excitement are the 142 principal investigators from the U.S. and eight foreign countries who will be receiving nearly 50 pounds of lunar material as the two-month quarantine period nears an end.

Speculation on the presence and concentration of rare earths runs high. A number of the principal investigators will be using highly sophisticated techniques to seek out traces of the rare earths including mass spectrometry, neutron activation, and emission spectroscopy.

Among the principal investigators involved in the search for rare earths are: P.W. Gast, Lamont Geological Observatory; L.A. Haskin, University of Wisconsin; A.W. Helz, U.S. Geological Survey; T.P. Kohman, Carnegie Institute of Technology; V.R. Murthy, University of Minnesota; G.W. Reed, Argonne National Laboratory; and R.A. Schmitt, Oregon State University.

The preliminary findings of these studies will be presented in Houston by the principal investigators three months after they receive their samples about September 20.

Not So Refractory PrP

In striking contrast to the high melting point of praesodymium monophosphide, 2850 ± 50°C, reported in the last issue of *RIC News*, is the 2400°C melting point for non-stoichiometric PrP observed by E. Francheschi and G.L. Olcese, *J. Phys. Chem. Solids* 30, 903 (1969). This reported melting point places PrP as about the eighth highest melting rare-earth compound.

Non-stoichiometry in PrP was determined by evaluating the variation of the lattice constant and density with composition. Quasi-stoichiometric phases occurred in the composition range PrP to $PrP_{0.85}$. The magnetic properties of these phases showed that the effective valency of Pr was approximately 3.3, and that PrP could not be regarded as a simple ionic compound.

Metamagnetic Eu_3O_4

A Russian team headed by A.A. Samakhvalov has measured the magnetic properties of Eu_3O_4 single crystals (*Zh. Eksp. Teor. Fiz.* 54, 1341 [1968]). They conclude that Eu_3O_4 is metamagnetic with a strong magneto-crystalline anisotropy and not a ferromagnet as proposed in earlier studies which had examined only polycrystalline samples. A metamagnetic material is one which is antiferromagnetic at low applied magnetic fields, but becomes ferromagnetic when the field is high enough to change the spin alignment.

They believe that the magnetic structure of Eu_3O_4 consists of ferromagnetic linear chains with antiferromagnetic coupling between chains. Neutron diffraction studies, however, are needed to confirm this proposed structure.

OXIDE ELECTROLYTES

A double cell containing two combinations of oxides (ZrO_2-CaO, ThO_2-Y_2O_3) to measure emf values over a wider range of oxygen pressures than has been heretofore possible is described by Tretyakov and Muan in *J. Electrochem. Soc.* 116, 331 (1969).

The ZrO_2-CaO electrolyte permits cell operation at high oxygen pressure, and the ThO_2-Y_2O_3 electrolyte at very low oxygen pressures. The electrolyte compositions are 85 m/o ZrO_2-15 m/o CaO and 92 m/o ThO_2-8 m/o Y_2O. The cell is described and its behavior and operating conditions are discussed.

ROMANIAN MAGNETISM

A comprehensive review of the rare-earth elements has just come to *RIC News'* attention. This book, *Magnetismul Pǎminturilor Rare* [Magnetism of the Rare Earths] by I. Pop, was published by Editura Academiei Republicii Socialiste Romǎnia, Bucharest (1968).

The first chapter is concerned with basic definitions and behaviors, the magnetic properties of ionic compounds of the rare earths, magnetic resonance phenomena, energy levels, and crystal field effects. The next three chapters deal exclusively with the magnetic behaviors of the metals, alloys and intermetallic compounds, and ferrites. The fifth and last chapter is on applications.

This 416-page book with almost 700 references costs 28 Lei (approx. $4.60).

INTERNATIONAL HAPPENINGS -

RE's in Grenoble, Zürich and Moscow

While in Europe during and after the French International Rare Earth Conference the Editor took the opportunity to visit several laboratories which are conducting research on the rare earths.

In Grenoble the Conference was held at the Nuclear Center, and the conferees had an opportunity to visit some of the laboratories there. Unfortunately, because of the lack of time I saw only their crystal growing laboratory. This laboratory is probably one of the largest of its kind in the world. They grow a variety of materials, including rare-earth garnets and aluminates, by a number of different techniques. Of course, the Nuclear Center, under the direction of L. Néel, and the National Center for Scientific Research's laboratories, under E.F. Bertaut, are well known for the excellent studies on the magnetic properties and x-ray and neutron crystallography of rare-earth materials.

After the Conference, I traveled by train from Grenoble to Zürich. In Zürich I visited the Institute of Solid State Physics of the Swiss Federal Institute of Technology which is headed by Dr. G. Busch. Dr. Busch's group is doing a great deal of work on the rare-earth non-metallic compounds RX, where X is N, P, As, Sb or Bi and R is a trivalent lanthanide, and EuX where X is O, S, Se or Te. They are primarily interested in semi-conducting ferromagnets and are studying magnetic and optical properties, crystal structures and photoemission. They have recently found that they can obtain polarized electrons (35% polarization) from photoemission of EuS (see *Solid State Comm.* 7, 775, 1969). A great deal of effort is also being spent on preparing high-purity samples and on better characterization of their materials for solid state studies.

After my visit to Zürich I traveled to Moscow to visit Professor E.M. Savitskii and his research group, the Laboratory of Rare Metals and Alloys in the Institute of Metallurgy of A.A. Baikov of the Academy of Sciences of USSR. Again, the shortage of time prevented my spending more than a day there. Professor Savitskii has five groups working under his supervision. Only one of these groups deals exclusively with the rare earths. The rare-earth group is primarily concerned with the determination of rare-earth alloy phase diagrams. Presently, those of La, Ce, Pr, Nd, Gd, and Sc with a variety of other metals including other rare earths are of greatest interest. Other groups which deal with thermionic emission, super-conductivity, and rhenium alloy chemistry only indirectly or occasionally work with the rare earths. A great deal of their work is directed toward finding technological applications, especially in electronic and electrical areas.

RARE EARTHERS on the move

Dr. Therald Moeller (RE complexes), professor of chemistry at the University of Illinois, will become chairman of the Department of Chemistry at Arizona State University, Tempe, in September. Moeller replaces Dr. LeRoy Eyring (RE oxides), chairman of the Arizona State Chemistry Department for the past 8 years, who returns to research and teaching.

At the AEC's Ames Laboratory, Iowa State University, Ames, Dr. V.A. Fassel (RE analytical spectroscopy) has been named deputy director to replace Dr. Morton Smutz (RE liquid extraction). Smutz is now associate dean and director of research in the College of Engineering, University of Florida, Gainesville. A member of the Ames Laboratory staff since 1942, Fassel is also a professor of chemistry at Iowa State University.

Alloy Advances

SUPERALLOYS

The addition of lanthanum, cerium or yttrium to superalloys used for marine turbine applications has proved to be beneficial in increasing the high temperature corrosion resistance of these alloys. Lanthanum or cerium is added to the nickel-based superalloys and yttrium to the cobalt-based alloys. Without the 0.1 to 0.2% rare-earth addition the corrosion rate may be as much as ten times more severe.

MAGNESIUM

The American producers of mischmetal for alloy additions to magnesium expect an increase in output during the next few years, because of the interest shown by U.S. foundries for a magnesium-zinc-rare earth-zirconium alloy (ZE41) for a casting alloy. Although this alloy has been widely used in Europe for many years, it is just becoming popular in America.

The improved castability, lower reject rate and better welding efficiency of ZE41 over the standard casting alloys (magnesium-aluminum-zinc alloys) has all but turned the tide in its favor, even though the costs are slightly higher.

COPPER

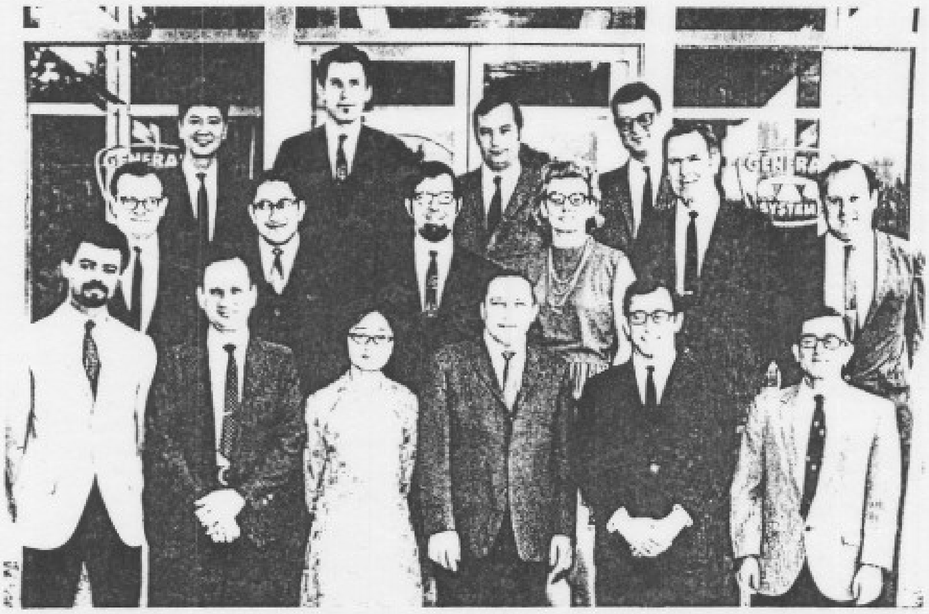
The addition of 2 vol % Y_2O_3 to OFHC (oxygen-free high-conductivity) copper as a fine dispersion increases the strength by a factor of 5 over hard-drawn OFHC copper without altering the electrical conductivity. Although many applications require high-strength - high-conductivity copper, the use of Y_2O_3 in these materials will be given serious competition from Al_2O_3.

Reviews "Terres Rares"

A review, *Les Éléments Des Terres Rares,* by J. Flahaut has been published by Masson et Cie, Editeurs, Paris (1969) 165 pp. Topics covered are general properties, history of the periodic classification, natural abundance, extraction and separation procedures, preparation and properties of the metals, compounds, and the uses and applications.

GT&E Laboratories –

LUMINESCENT MATERIALS GROUP



LUMINESCENT MATERIALS GROUP - In the front row from left are Brian O'Reilly, Frank Avella, Lily Ho, Frank Palilla, Richard Klein and Victor Abbruscato. Pictured in the center row from left are Vincent Meyer, Thomas Sisneros, Robert Amster, Maija Tomkus, Thomas Peters and Samuel Natansohn. In the back row from left are Taisuke Yoshioka, Ojars Sovers, Rene Simon and Gleb Gashurov.

Luminescent materials research at the Bayside Research Center of the General Telephone & Electronics Laboratories located at Bayside, New York, covers all aspects of luminescence in inorganic solids. This program, under the direction of Frank C. Palilla, emphasizes research on rare-earth phosphors because of their tractability to theoretical investigations and because of their importance in color TV and lighting applications.

The basic studies cover the gamut of excitation, energy transfer and emission processes in inorganic phosphor systems. Examination of the response of phosphors to various excitation modes helps to identify the processes by which energy is absorbed or lost, and thereby to determine the ultimate radiant efficiencies obtainable.

Studies of the lifetimes of excited states clarify the host-activator and activator-other atom interactions involved in energy transport. In addition, precise spectroscopic studies of intensities and positions of the discrete emission characteristics observed with rare-earth activators in selected hosts are used to describe quantitatively the internal crystalline field experienced by the activator.

Concomitantly, exploratory synthesis research is carried out in a search for materials with high luminescent response throughout the visible spectral range. Emphasis is placed on the coupling of visibly emitting lanthanide ion activators (Ce, Sm, Eu, Tb, Dy, Ho, Er, Tm, Yb) to hosts containing rare-earth cations (Y, La, Gd, Lu). The significant features of the latter are that they are optically inert and they easily accommodate the former.

The experimental phosphors resulting from this research are evaluated for commerical use, and significant new developments are promptly transferred to the Chemical and Metallurgical, Lighting, and Electronic Components Divisions of Sylvania Electric Products Inc., a subsidiary of General Telephone &

(Continued on Page 8)

Support RIC

(Continued from Page 1)

Co., Ltd., Japan; Typpi Oy, Finland; and Wako Bussan Co., Ltd., Japan.

The first industrial support of RIC came from these companies: American Potash, Grace, Molycorp, Research Chemicals, and Ronson.

The resumption of RIC's inquiry answering service is a direct result of increased industrial support for Fiscal Year 1970. A half-time staff member has been added to provide this and other services (see story on Page 2). Despite RIC's curtailed activities, information requests are running 50% ahead of a year ago.

Although it appears that the Center will be operating at a near normal level through July 1970, its future is still uncertain. With little likelihood of Federal support, RIC's programs will depend on financial aid from additional companies in the rare-earth business.

The Center needs grants totalling $10,000 annually in addition to the support provided by Iowa State University to meet minimum objectives. To date about 60% of the needed funds have been received or pledged. If your firm would like to join our present benefactors in supporting RIC, contact Director K.A. Gschneidner, Jr.

"A continuing commitment on the part of rare-earth users and producers will enable the Center to plan farther into the future," according to Gschneidner. "Until then, we must necessarily operate on a year-to-year basis," he concluded.

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Staff Writers

✡✡✡✡✡✡✡✡✡✡✡✡ ✡ Reports ✡ ✡ Booklets ✡ ✡ Brochures ✡ ✡✡✡✡✡✡✡✡✡✡✡✡

GERMAN BOOKLET

The June 1969 issue of *Goldschmidt informiert,* 1/69 Nr. 6, contains seven articles on the metallurgical applications of the rare earths. These articles, which are all written in German, deal with: (1) a general survey by I.S. Hirschhorn*; (2) a direct high temperature chlorination process by W. Brugger and E. Greinacher; (3) cast iron with spherical graphite by W. Brugger; (4) rare-earth steels - Brugger; (5) rare-earth magnesium alloys - Brugger; (6) rare earths in copper and copper-base alloys by W. Hilgers; and (7) rare earth-cobalt permanent magnets by C. Herget.

This issue is available free and may be obtained by writing to Th. Goldschmidt A.-G., 43 Essen 1, Postfach 17, Germany.

*A closely related paper by Hirschhorn, "Metallurgical Applications of the Rare Earth Metals" (in English) appeared in the June 1969 issue of *Modern Castings.*

Magnetic Semiconductors

The state-of-the-art on magnetic semiconductors has been summarized in an excellent review by S. Methfessel and D. C. Mattis, p. 389 in *Handbuch der Physik [Encyclopedia of Physics]*, Vol. XVIII/1 (1968). Although it covers all known magnetic semiconductors, about half of the 180-page article deals with the rare-earth magnetic semiconductors, especially the europium 1:1 chalcogenides.

The review covers all aspects of these materials, including band structure; theory of transport properties; indirect exchange, both theory and experimental evidence; optical properties; and electrical properties. This chapter is highly recommended for anyone actively working or interested in these materials.

GEOCHEMICAL PROSPECTING

The occurrence of trace elements such as cobalt, europium, and scandium in ocean floor samples may be useful in determining origins of undersea sediments.

Texas A and M University's Activation Analysis Research Laboratory is developing methods which use these elements in "geochemical prospecting" on the ocean floor. Although work is now limited to analyses of five major elements – silicon, oxygen, aluminum, magnesium, and iron.

MAGNETISM IN TECHNOLOGY

In an invited paper presented at the 14th Annual Magnetism Conference, I. S. Jacobs discussed the "Role of Magnetism in Technology," [his complete talk is published in the March, 1969, issue of *J. Appl. Phys.* 40, 917]. Jacobs notes that magnetism has an economic impact of over 1% on the gross national product of America, and presumably a similar percentage in other technologically advanced countries. The magnetism market, research, history, and esoteric role of magnetism are all discussed.

In addition to Jacob's paper, this issue of *J. Appl. Phys.* contains about 75 more papers dealing directly or indirectly with rare-earth materials.

Thermocouple Insulator

Yttrium oxide was found to be better than BeO and as good as ThO_2 for thermocouple insulators at temperatures between 1800 and 2000°C using tungsten/25% (or 3%) rhenium-tungsten thermocouple wires and Ta, Mo, Re, W and Nb Sheaths. It was found that Y_2O_3-insulated thermocouples maintained their calibration for more than one month at 2000°C. [J.W. Droege, *et al., Battelle Memorial Institute Report* BMI-X-10246 (November, 1968)]

Publications Available

Fraternal Fifteen, an elementary introduction to rare earths, may be obtained free from RIC.

IS-RIC-1, *Rare Earth Products Catalog*, is available for $3.00 from Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Springfield, Virginia 22151, USA.

Back numbers of *RIC News* are available as follows: Vol. III, Nos. 2, 3 and 4 and Vol. IV., Nos. 1 and 2 are available free from RIC.

Xerox copies of earlier numbers can be obtained from Iowa State University Library, Reference Department, Ames, Iowa 50010. Charge is $.10/page; Minimum order, $1.00. Bold face numbers in the table below indicate number of pages in earlier issues, e.g. Vol. II, No. 2 consisted of 10 pages.

Vol.	Issue Number 1	2	3	4
I	4	8	4	8
II	8	10	4	4
III	4	-	-	-

Luminescent Materials Group
(Continued from Page 7)

Electronics Corporation. An example of such a development is the YVO_4: Eu phosphor which has had a major impact in the lighting, television and rare-earth chemical industries.

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RARE-EARTH INFORMATION CENTER NEWS

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Volume IV | December 1, 1969 | No. 4

AIME Alloy Theory Conference

Eight papers on the "Alloy Theory of the Rare-Earth Metals" were presented at the Fall Meeting of the Metallurgical Society of the Amer. Inst. of Mining Met. and Pet. Engr. The first paper, "Band Structures" by J. O. Dimmock, Massachusetts Institute of Technology, discussed the theoretical calculations of the electronic structures of the rare-earth metals. Several different methods for calculating the band structures were discussed and the usefulness and limitations of each were summarized.

"Transport and Magnetic Properties" by Sam Legvold, Iowa State University, dealt with rare-earth metal single crystals. The influence of the magnetic structures and band overlap on some of the properties were clearly demonstrated in several instances.

The results of neutron inelastic scattering experiments being carried out in several different laboratories were summarized by S. K. Sinha of Iowa State University in his talk, "Neutron Scattering." He noted that the phonon dispersion curves for the normal hexagonal rare-earth metals were similar to one another and that the number of 4*f* electrons does not affect these curves. Furthermore, he pointed out that they have strong long-range forces within the basal plane but not between layers.

The results of "Mossbauer and Nuclear Magnetic Resonance" studies on the rare-earths was reviewed by G. M. Kalvius, Argonne National Laboratory. The similarities and differences between these two techniques were briefly summarized. The experimental difficulties in using these techniques to study rare earths and some of the significant and important results were noted.

C. C. Koch, Oak Ridge National Laboratory, spoke on "Solid Solution Intra-Rare-Earth Alloys." The results from different laboratories were summarized, and several diverse explanations dealing with the existence of the various phases observed in these alloys were discussed.

"Solid Solutions with Non-Rare-Earth Metals" was presented by K. A. Gschneidner, Jr., Iowa State University. He stated that information gleaned from these studies has shed new light on the factors which influence the formation of solid solution alloys.

Hugo Steinfink, University of Texas, delivered a paper entitled "Crystal Chemistry of Semi-Metallic-Rare-Earth Compounds." The major portion of his talk was concerned with the sulfides, selenides and tellurides, especially the R_3X_4-R_3X_2 region in the rare-earth(R)-chalcogenide(X) systems.

The final paper was presented by W. B. Pearson, University of

(Continued on Page 4)

New Service from RIC

The Rare-Earth Information Center is now in a position to offer an additional service to the scientific and technological community. RIC is providing extensive surveys or searches and in-depth analyses on a cost basis. However, we will continue to answer most inquiries on a no charge basis as in the past, except for those which require a large amount of staff time to answer. We will inform the requester beforehand if there will be a charge made for our services.

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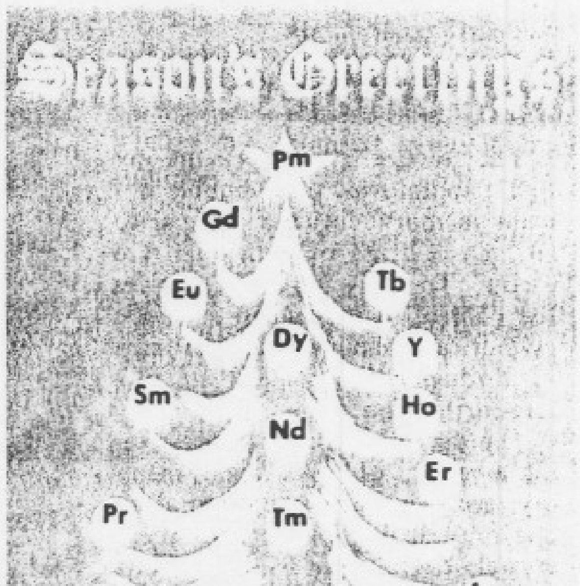


More RIC Support

Two more rare-earth producers, Forskningsgruppe for Sjeldne Jordarter (Rare Earth Research Group) of Oslo, Norway and Nippon Yttrium Company, Ltd. of Tokyo have joined the other 15 leading companies which are now supporting RIC.

Rare Earth Pioneer, Spedding, is Honored

Rare-earth pioneer Frank H. Spedding has been honored for his scientific contributions by both the Society for Applied Spectroscopy and the Franklin Institute of Philadelphia.

The Franklin Institute awarded Spedding its Francis J. Clamer medal for his "many important contributions to the science of extractive metallurgy . . . and for his pioneering contributions to rare-earth metallurgy." The Society for Applied Spectroscopy named Spedding to honorary membership citing him for his continuing studies on the nature of solids by means of spectroscopy, with major work on rare-earth compounds.

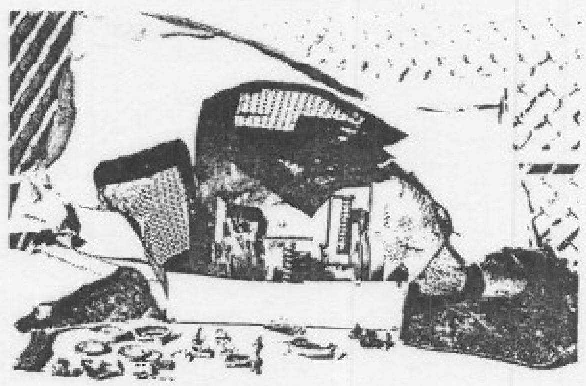
Bell Bubbles

The recent announcement by Bell Laboratories of a bubble domain memory device may lead to an increased use of individual rare earths. The development involves the control of very small magnetic cylindrical domains (bubbles) moving through a thin single crystal of a rare-earth orthoferrite.

The device is capable of performing a variety of tasks; logic, memory, switching and counting, all in one crystal. A cubic inch of these crystals could store 15 million bits of information with a power consumption of a few ten thousandths of a watt. The space and power savings each are of the order of 10^5 over present devices.

To date the most promising materials are orthoferrites containing samarium, terbium, dysprosium and thulium.

REactive in Certain Media



The Spex Mixer/Mill pictured at right was demolished and a technician was injured as a result of an explosion which occurred when an attempt was made to grind 20 g of samarium powder in approximately 20 cc of Freon 113 (1,1,2-trichlorotrifluoroethane). It was reported that detonation was almost instantaneous. Subsequent investigation revealed that the explosion was caused by the generation of fresh metal surface in the presence of the chlorinated halocarbon as a result of the grinding operation. It is thought that other RE's will react in the same manner when ground in the presence of chlorinated halocarbons.

25

RIC has just published *25 Years of Rare Earths -- A Bibliography of Rare-Earth Research Papers and Reports Published by the Ames Laboratory from Its Founding to Its 25th Anniversary,* by Joan E. Smith, Charla C. Bertrand, and Karl Gschneidner, Jr., August 1968, 241 pages.

This report is divided into three sections: papers published in journals, conference proceedings, and books; university theses and U. S. Atomic Energy Commission reports; and patents on rare-earth processes. Subject, materials, and author indexes are included. *To obtain a copy, order USAEC Report IS-RIC-2 from the Clearinghouse for Federal and Scientific Technical Information, Springfield, Virginia 22151, U.S.A.; the price is $3.00.*

Trademark Protection For RIC Symbol

The United States Patent Office has granted trademark protection to the U. S. Atomic Energy Commission for the symbol used by the Rare-Earth Information Center. The trademark is only the second granted to the AEC.

RIC's trademark which appears on all RIC publications consists of a large triangle enclosing a smaller, inverted triangle. The chemical symbols for the rare earths are printed in the outer triangle from the apex down according to decreasing number of unpaired 4*f* electrons. The inner triangle with the cross bar is the alchemist's symbol for earth, and this combined with the Latin word for rare (rarus) gives "rare earth."

In addition to using the trademark on the heading of *RIC News*, the Center uses it on brochures concerning the Center, and on the covers of its technical reports. And that, sharp-eyed readers, is why the ® appears next to the symbol on this issue.

Magnetic Review

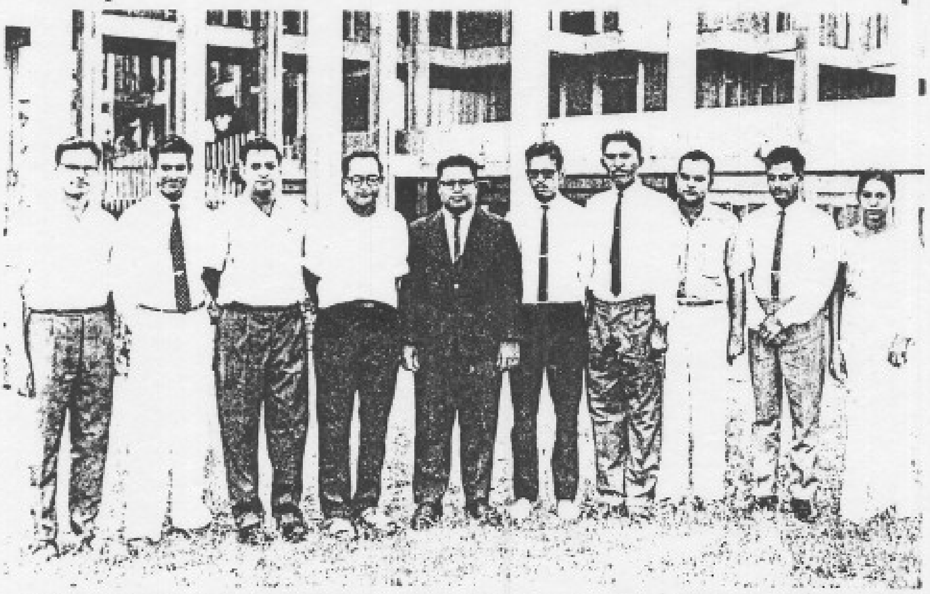
The 1967 technical literature covering the magnetic properties of rare-earth materials is summarized in *Magnetism and Magnetic Materials, 1968 Digest*, H. Chang and T. R. McGuire, eds. (Academic Press, New York, 1968) 315 pp., 2000 references.

The chapters on rare earths cover work on magnetic moment, paramagnetic susceptibility, ordering temperature and structure, exchange mechanism, and anisotropy for the metals, alloys, and com-

(Continued on Page 3)

Indian Institute of Technology --

Kanpur Rare-Earth Research Group



RARE-EARTH RESEARCH GROUP – Pictured from left are Dr. S. N. Bhat, Dr. G. V. Subba Rao, Mr. M. Natarajan, Dr. A. S. N. Murthy, Professor C. N. R. Rao, Mr. S. Ramdas, G. Rama Rao, Mr. G. C. Chaturvedi, Dr. M. S. Tomar and Miss Abha Goel.

Professor C. N. R. Rao and his research group are actively engaged in research in the areas of solid state chemistry, chemical spectroscopy and molecular structure. Much of research work in solid state chemistry is related to rare earths. The specific problems in rare earths are the following:

1. This group has been interested in the phase transformations and equilibria in rare-earth oxides for some years. They have studied the phase transformations of the sesquioxides and the formation of PrO_2 and TbO_2 by acid leaching of the non-stoichiometric oxides. Recently, they have examined the origin of the anomalously high entropy changes associated with the oxidation of Pr_2O_3 and Tb_2O_3 to non-stoichiometric oxides.

2. The mechanism of electrical transport in rare-earth oxides has been examined in the light of the polaron model. Mixed conduction in oxides of the type TiO_2-Y_2O_3 and CeO_2-Y_2O_3 has been studied with a view to understanding defect structures.

3. Electrical, optical (I. R. and U. V. spectra) and dielectric properties of rare earth perovskites of the general formula, $LnZO_3$ (Z = ion of the first transition metal series) are being studied extensively. These properties are interpreted in terms of the localized and collective be-

(Continued on Page 4)

EUROPIUM STAIN

A europium chelate has been reported as a fluorescent stain for microorganisms by W. L. Schaff, Jr., D. L. Dyer, and K. Mori, *J. Bacteriol.* 98, 246 (1969).

One of the best chelates was found to be tris (4,4,4-trifluoro-1-(2-thienyl)-1,3-butanediono) europium, $Eu(TTA)_3$, which is formed by the reaction of europium salts (acetate, chloride, or nitrate) with the organic ligand.

Eu $(TTA)_3$ has widely separated activation and emission lines and is easily activated by the 365 nm mercury line. The organic portion of the molecule absorbs ultraviolet light, and transfers the energy to the europium ion which emits light in a narrow band at 613 nm.

Apparently one or more components of the cell binds europium firmly giving a bright and uniform stain. The best results were obtained using 10^{-3}M Eu(TTA) in 50% ethanol, although a number of organic solvents or buffered aqueous solutions also gave good results.

Superconducting Rare Earths

Recently scientists at the University of California's Los Alamos Scientific Laboratory reported the preparation of a new high-temperature yttrium-thorium sesquicarbide superconductor. Krupka, Giorgi, Krikorian and Szklarz state in their *J. Less-Common Metals* (19, 113, 1969) paper that the maximum temperature, 17°K, was found for an alloy of the composition $Y_{0.7}Th_{0.3}C_{1.55}$.

This compound has the body-centered cubic Pu_2C_3-type structure and must be prepared by high-pressure high-temperature techniques.

Does this study open the door to a new class of high-temperature superconductors much like the class based on the cubic $W_3O(\beta$-W) type structure? We at RIC believe it does – but only time will tell.

Review

(Continued from Page 2)

pounds. There are additional references to rare-earth work under the chapters on theory, dilute systems, nuclear magnetism, and magnetoelastic phenomena. A material index by chemical symbols is included.

The digest is published annually, surveying the literature, books, and conferences of the preceding year; the price of the 1968 volume is $13.00.

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Nancy Kippenhan and W.H. Smith
Staff Writers

Rare Earths In the News

RONSON ACQUISITION

Ronson Corporation has acquired British Flint & Cerium Manufacturers, Ltd., which now becomes a division of Ronson Products, Ltd. The mischmetal manufactured by British Flint & Cerium will be primarily used in the United Kingdom for lighter flints and alloy additives.

LANTHANUM ELECTRON GUN

A patent for an improved electron gun which utilizes LaB_6 as the cathode from which electrons are emitted has been granted to the International Business Machines Corporation. The improved gun is the invention of Dr. Alec N. Broers. The gun is said to have five times the "brightness" of those made with the usual tungsten hairpin-shaped filaments.

Kanpur

(Continued from Page 3)

haviour of the d-electrons. Detailed studies on ortho-chromites, -manganites and -ferrites have been completed and presently cobaltites, nickelites and titanites are being examined.

4. Optical spectra of rare-earth ions doped in CaF_2 are being examined to understand the defect equilibria and energetics.

5. Infrared spectra and thermal decompositions of a number of rare-earth compounds (carbonates, nitrates, nitrites, acetates, formates etc.,) have been investigated to establish the reaction modes and the nature of metal-anion bonding. Heavier rare-earth compounds generally decompose at lower temperatures due to the greater covalency of the metal-oxygen bonds; in these compounds distinct bands are seen in the infrared spectra due to the metal-oxygen stretching vibrations.

Rare! Earthly Goofs

Vol. IV, No. 3, September 1969.

In the story on the June 1969 issue of *Goldschmidt informiert*, articles 3, 4 and 5 were written by W. Bungardt and not by W. Brugger as reported.

AIME

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Waterloo (Canada) on "Crystal Chemistry of Metallic-Rare-Earth Compounds." He noted that the rare-earth-metallic compounds form most of the common-type structures found for metallic compounds, except in the cases where the large size of the rare-earth metal atom prevents their formation – such as sigma and related phases.

The papers presented at this symposium will not be published as a conference proceedings. However, most of the information presented at the conference has been or will be published in the usual journals.

Service

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In keeping with our previous tradition, all information inquiries and our new services are kept confidential unless otherwise directed by the requester. For further information write the Director of RIC, Dr. Karl A. Gschneidner, Jr.

RE Lubricants

CeF_3 and LaF_3 have been found to be effective in reducing metallic wear in air or argon atmospheres at temperatures up to 1000°C, according to H. E. Sliney of National Aeronautics and Space Administration's (NASA) Lewis Research Center, Cleveland, NASA TN D-5301, July 1969.

During wear experiments the flouride particles coalesced and flowed plastically in the contact areas forming a thin adherent film on Inconel sliding surfaces used in the study. Friction coefficients ranged from 0.1 to 0.4 and were fairly constant over a large temperature range. CeF_3 and LaF_3 were also found to be useful in lubricating nickel-base superalloys.

The lubricating properties of CeF_3 and LaF_3 combined with their chemical stability and high melting points make them attractive lubricants for special applications such as power transmission devices, especially at high temperatures.

The oxides of La and Ce were also investigated under the same conditions and found to be poor lubricants below 700°C, although there was some indication that they might have lubricating ability at very high temperatures (see *RIC News* Vol II, No. 4, p. 2, December 1967).

TROMBE NAMED TO C.N.R.S. BOARD

Felix Trombe, formerly director of the Rare Earth Laboratory of the French National Center for Scientific Research (C.N.R.S.), has been named to a three-year term as president of the Laboratory's board of directors. His appointment was effective in October 1969.

J. Loriers has succeeded Prof. Trombe as director of the Rare Earth Laboratory, and P. Caro has been appointed assistant director. Prof. Trombe will continue his research interests in rare-earth metallurgy in his new post with C.N.R.S.

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